CLAIMS

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1. An adaptive directional sound processing system, comprising:

a least two microphones spaced apart by a predetermined distance, each of said microphones producing an electronic sound signal;

a delay circuit that delays the electronic sound signal from at least one of said microphones by an adaptive delay amount;

a subtraction circuit operatively connected to said microphones and said delay circuit, said subtraction circuit producing an output difference signal from the electronic sound signals following said delay circuit; and

a delay amount determination circuit operatively coupled to receive the output difference signal, said delay amount determination circuit produces a delay control signal that is supplied to said delay circuit so as to control the adaptive delay amount.

2. An adaptive directional sound processing system as recited in claim 1, wherein the adaptive delay amount varies so as to directionally suppress undesired sound.

3. An adaptive directional sound processing system as recited in claim 1, wherein the adaptive delay amount induced by said delay circuit operates to minimize the energy amount of the output difference signal.

4. An adaptive directional sound processing system as recited in claim 1, wherein the adaptive delay amount induced by said delay circuit operates to minimize the energy amount of the output difference signal while not significantly attenuating sound arriving at said microphones from a predetermined direction.

5. An adaptive directional sound processing system as recited in claim 1, wherein said adapting operates to minimize the energy amount of the output difference signal so as to maximize Signal-to-Noise Ratio (SNR).

6. An adaptive directional sound processing system as recited in claim 1, wherein said adaptive directional sound processing system resides within a hearing aid device.

7. An adaptive directional sound processing system, comprising:

a least two microphones spaced apart by a predetermined distance, each of said microphones producing an electronic sound signal;

a delay circuit that delays the electronic sound signal from at least one of said microphones by an adaptive delay amount;

a logic circuit operatively connected to said microphones and said delay circuit, said logic circuit producing an output signal from the electronic sound signals following said delay circuit; and

a delay amount determination circuit operatively coupled to receive the output signal, said delay amount determination circuit produces a delay control signal based on the output signal, the delay control signal being is supplied to said delay circuit so as to control the adaptive delay amount.

8. An adaptive directional sound processing system as recited in claim 7, wherein the adaptive delay amount varies so as to directionally suppress undesired sound.

9. An adaptive directional sound processing system as recited in claim 7, wherein the adaptive delay amount induced by said delay circuit operates to minimize the energy amount of the output signal.

10. An adaptive directional sound processing system as recited in claim 7, wherein the adaptive delay amount induced by said delay circuit operates to minimize the energy amount of the output signal while not significantly attenuating sound arriving at said microphones from a predetermined direction.

11. An adaptive directional sound processing system as recited in claim 7, wherein said adapting operates to minimize the energy amount of the output signal so as to maximize Signal-to-Noise Ratio (SNR).

12. An adaptive directional sound processing system as recited in claim 7, wherein said adaptive directional sound processing system resides within a hearing aid device.

13. An adaptive directional sound processing system as recited in claim 7, wherein the adaptive delay amount induced by said delay circuit is controlled such that a delay increment is added to a previously determined adaptive delay amount.

14. An adaptive directional sound processing system as recited in claim 13, wherein the delay increment is determined based on change in energy on the output signal.

15. An adaptive directional sound processing system as recited in claim 13, wherein the change in energy selects one of two possible delay increments.

16. An adaptive directional sound processing system as recited in claim 15, wherein the two possible delay increments are a previous delay increment and an inverse previous delay increment.

17. An adaptive directional sound processing system as recited in claim 13, wherein the delay increment is determined by multiplying a previous delay increment by a change in energy on the output signal.

18. An adaptive directional sound processing system as recited in claim 13, wherein the delay increment is determined by scaling a change in energy on the output signal and then multiplying a previous delay increment by the change in energy on the output signal.

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See rejection of claim 14

19. An adaptive directional sound processing system as recited in claim 7, wherein said delay amount determination circuit comprises:

an energy estimator that receives the output signal and produces an energy estimate signal; and

a delay generator that receives the energy estimate signal and generates a delay signal based on the energy estimate signal.

20. An adaptive directional sound processing system as recited in claim 19,

wherein said energy estimator operates at a first sampling rate and said delay generator operates at a second sampling rate, the first sampling rate being greater than the second sampling rate, and

wherein down sampling is performed between said energy estimator and said delay generator to accommodate difference in the first and second sampling rates.

21. An adaptive directional sound processing system as recited in claim 19, wherein said energy estimator uses a first time constant and said delay generator uses a second time constant, the first time constant being faster that the second time constant.

22. An adaptive directional sound processing system, comprising:

at least two microphones (101, 110) spaced apart by a predetermined distance, each of said microphones producing an electronic sound signal;

a delay circuit (114) that delays the electronic sound signal from at least one of said microphones by an adaptive delay amount;

logic means (121) for producing an output signal from the electronic sound signals following said delay circuit; and

delay determination means for producing a delay control signal based on the output signal, the delay control signal being is supplied to said delay circuit so as to control the adaptive delay amount.

23. A method for adaptively controlling delay induced on a sound signal so that unwanted noise is directionally suppressed, said method comprising:

(a) producing a difference signal from at least first and second sound signals respectively obtained by first and second microphones;

(b) estimating an energy amount of the difference signal; and

(c) producing a delay signal to control a delay amount induced on at least one of the first and second sound signals based on the energy amount of the difference signal.

24. A method as recited in claim 23, wherein said method further comprises:

(d) inducing the delay amount on at least one of the first and second sound signals.

25. A method as recited in claim 24, wherein following said inducing (d) said method (e) repeats said operations (a) – (d) so that the delay amount is dynamically adjusted so as to directionally suppress the unwanted noise.

26. A method as recited in claim 23, wherein the sound signal is provided by a hearing aid, and wherein said method is performed by the hearing aid.

27. An adaptive delay method for directional noise suppression in a hearing aid device, the hearing aid device having at least first and second microphones, said method comprising:

receiving first and second microphone outputs;

delaying at least the second microphone output by an adaptive delay amount;

combining the first microphone output and the delayed second microphone output to produce an output signal;

estimating an energy amount associated with the output signal; and

adapting the adaptive delay amount based on the energy amount.

28. A method as recited in claim 27, wherein said adapting operates to minimize the energy amount of the output signal while not significantly

attenuating sound arriving at the first and second microphones from a predetermined direction.

29. A method as recited in claim 27, wherein said adapting operates to minimize the energy amount of the output signal so as to maximize Signal-to-Noise Ratio (SNR).

30. A method as recited in claim 27, wherein said combining comprises adding the first microphone output and the delayed second microphone output.

31. A method as recited in claim 27, wherein said combining comprises subtracting the first microphone output and the delayed second microphone output.

32. A method as recited in claim 27, wherein said adapting determines the adaptive delay amount based on change in energy on the output signal.

33. A method as recited in claim 32, wherein the change in energy on the output signal selects one of two possible delay increments.

34. A method as recited in claim 33, wherein the two possible delay increments are a previous delay increment and an inverse previous delay increment.

35. A method as recited in claim 27, wherein said adapting of the adaptive delay amount comprises multiplying a previous delay increment by a change in energy on the output signal.

(33) 36. A method as recited in claim 27, wherein said adapting of the adaptive delay amount comprises scaling a change in energy on the output signal and then multiplying a previous delay increment by the change in energy on the output signal.

37. A method for adaptively controlling delay induced on a sound signal in a multi-microphone directional processing system so that unwanted noise is directionally suppressed, said method comprising:

(a) receiving at least first and second sound signals respectively obtained by first and second microphones;

(b) delaying at least one of the first and second sound signals by a plurality of different delay amounts;

(c) producing, following said delaying (b), a plurality difference signals from at least first and second sound signals respectively obtained by first and second microphones;

(d) estimating energy amounts for each of the difference signals; and

(e) choosing the one of the difference signals as an output of the directional processing system based on the energy amounts of the difference signals.

38. A method as recited in claim 37, wherein the sound signals are provided by a hearing aid, and wherein said method is performed by the hearing aid.

39. An adaptive directional sound processing system, comprising:

at least two microphones spaced apart by a predetermined distance, each of said microphones producing an electronic sound signal;

a plurality of delay circuits that each delay the electronic sound signal from at least one of said microphones by a different delay amount;

logic means for producing candidate output signals from the electronic sound signals following said delay circuits; and

output selection means for selecting one of the candidate output signals as an output based on energy levels of the candidate output signals.